

Supplemental Information

Behavioural results

Supplemental Table 1 details all estimated parameter values and model fit scores.

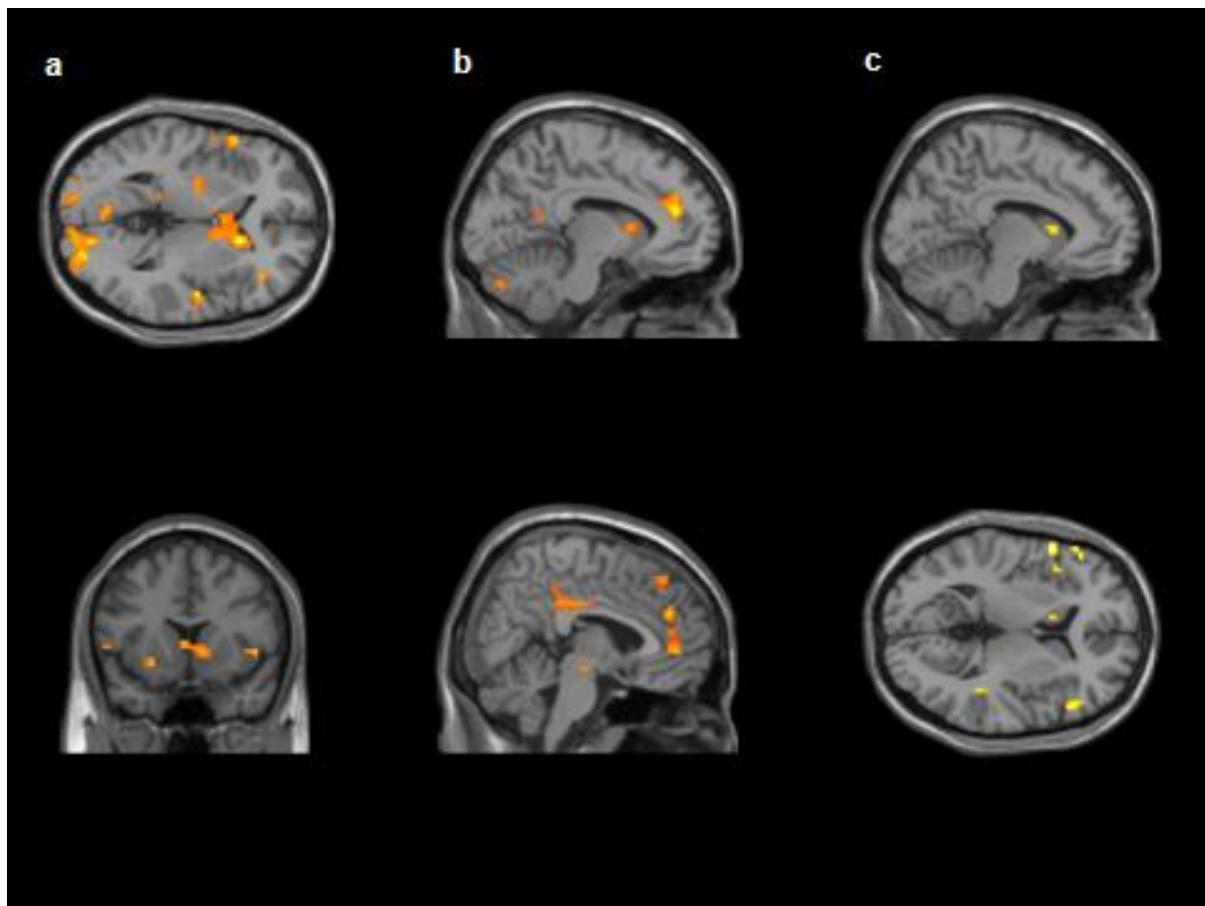
Subject	K	r	β	Likelihood
Placebo				
1	0.0628	0.0017	2.2152	28.4596
2	0.0419	0.2441	0.2228	51.3470
3	0.0277	-0.0067	15.2430	120.3000
4	0.0209	0.0164	2.0751	87.1300
5	0.0048	0.0144	1.3654	70.1930
6	0.0029	-0.0005	1.5623	35.8910
7	0.0287	0.0048	3.2314	93.5860
8	0.0214	-0.0036	11.2640	128.8000
9	0.0289	0.0622	1.3167	83.2310
10	0.0596	0.0062	2.6162	75.9650
11	0.0028	0.0008	1.8798	36.0990
12	0.0053	-0.0103	5.5744	56.2900
13	0.0003	4.3632	0.0008	98.2330
Group Likelihood				965.5246
median	0.0214	0.0048	2.0751	75.9650
L-Dopa				
1	0.0632	0.0057	0.9885	31.9848
2	0.0831	0.1335	0.6165	72.9960
3	0.0370	-0.0081	6.8638	102.9700
4	0.0276	0.0096	3.0759	95.3290
5	0.0581	0.0020	2.3475	72.0280
6	0.0052	0.0003	1.8404	56.6000
7	0.1122	0.0296	1.2354	57.8280
8	0.0384	0.0003	6.7470	113.1900
9	0.0447	0.0590	1.4010	76.7250
10	0.0723	0.0038	3.5184	86.4090
11	0.0052	-0.0040	5.5523	71.5230
12	0.0093	-0.0068	15.3960	108.8800
13	0.0239	0.0515	1.2321	74.5150
Group Likelihood				1020.9778
median	0.0384	0.0038	2.3475	74.5150

	Haloperidol			
1	0.0225	0.0589	0.6975	45.2045
2	0.0039	0.9326	0.0133	40.8100
3	0.0364	-0.0048	8.9844	117.8900
4	0.0175	0.0038	5.3303	109.2500
5	0.0036	0.0164	0.9746	61.0560
6	0.0023	0.0022	2.5209	58.0730
7	0.0679	0.0007	2.2905	69.9560
8	0.0452	-0.0002	5.0021	106.4100
9	0.1298	0.0047	2.0655	64.3990
10	0.0758	-0.0009	3.3843	82.8920
11	0.0024	0.0104	1.9480	60.9360
12	0.0014	-0.0106	5.1589	40.0820
13	0.0477	0.0619	1.7840	91.1970
Group Likelihood				948.1555
median	0.0225	0.0038	2.2905	64.3990

Supplemental Table 1. Parameter estimates of the discounted utility model (Eq. 2), softmax function (Eq. 1) and model fit scores for each subject in each drug condition. Determined using maximum likelihood estimation.

Imaging results

Supplemental Tables 2-4 and Supplemental Figure 1 detail the regions correlating with the three regressors (U , V , and D) solely in the placebo condition.



Supplemental Figure 1. **a** Regions correlating with the utility (U) of each option in the placebo condition. **b** Regions correlating with the discount factor (D) of each option in the placebo condition. **c** Regions correlating with the discounted utility (V) of each option in the placebo condition.

REGION	CLUSTER SIZE	MNI COORDINATES	Z VALUE
Region bordering putamen and amygdala (right)	22	[30 -3 -12]	4.45
Visual cortex	673	[12 -90 -9] [27 -48 -27] [-9 -99 -6]	4.43 3.91 3.86
Cerebellum	19	[-30 -75 -21]	4.04
Right superior temporal cortex	45	[63 -24 12]	3.93
Right caudate	114	[15 21 3] [21 24 -3] [9 6 -3]	3.80 3.30 3.23
Precentral gyrus	26	[51 -9 3]	3.63
Separans gyrus/ frontal operculum	27	[45 9 0]	3.52
Left inferior frontal gyrus	11	[-54 15 3]	3.37
Left thalamus / tail of caudate	30	[-13 -36 0] [-18 -30 6] [-15 -24 18]	3.33 3.05 3.05
Posterior cingulate / occipital gyrus	34	[12 -54 0] [-6 -72 3]	3.32 3.14
Left putamen	23	[-24 12 -9] [-24 6 -3]	3.23 3.17
Left putamen	28	[-27 -6 6]	3.23
Occipital gyrus	9	[15 -48 -3]	3.17
Dorsolateral PFC	5	[39 36 3]	3.23
Left superior temporal gyrus	14	[-57 -3 -6]	3.07
Ventral tegmental area	6	[15 -15 -27]	3.07
Internal capsule	12	[21 -18 9]	2.94

Supplemental Table 2. Regions correlating with the utility (U) of each option in the placebo condition alone.

REGION	CLUSTER SIZE	MNI COORDINATES	Z VALUE
Dorsolateral PFC	139	[48 27 18]	4.75
		[45 33 6]	3.39
		[54 42 6]	3.16
Superior temporal gyrus	160	[63 -36 -15]	4.74
		[57 -45 -15]	4.17
		[57 -45 -18]	3.91
Dorsolateral PFC	97	[51 24 30]	4.70
		[42 18 27]	4.16
		[51 15 30]	4.00
Anterior cingulate cortex	169	[-9 42 18]	3.91
		[6 42 27]	3.59
		[9 45 0]	3.56
Orbitofrontal cortex	11	[-24 39 -18]	3.87
Thalamus	21	[21 -36 6]	3.72
Rostral ACC / cingulate gyrus	27	[12 -51 18]	3.70
Superior temporal gyrus	92	[-51 -51 -21]	3.68
		[-48 -54 -6]	3.13
		[-60 -39 -18]	3.09
Posterior cingulate cortex	86	[-3 -9 33]	3.58
		[9 -24 33]	3.23
		[6 -33 33]	3.11
Dorsolateral PFC	35	[-39 18 24]	3.56
Frontomarginal Gyrus	35	[39 54 3]	3.54
Orbitofrontal cortex	11	[-24 39 -21]	3.41
Orbitofrontal cortex	10	[27 39 -6]	3.30
Caudate	12	[-9 9 6]	3.26
Inferior frontal gyrus (orbital)	11	[-39 36 3]	3.23
Ventral tegmental area / SN	8	[6 -18 -12]	3.15

Supplemental Table 3. Regions correlating with the discount factor (D) of each option in the placebo condition alone.

REGION	CLUSTER SIZE	MNI COORDINATES	Z VALUE
Inferior frontal gyrus (orbital)	21	[-57 12 6]	3.92
Dorsolateral PFC	37	[-45 33 18] [-51 33 6]	3.64 3.32
Lateral orbital gyrus / inferior frontal	22	[39 21 -15]	3.47
Dorsolateral PFC	23	[54 24 9]	3.38
Inferior frontal / lateral orbital gyrus	10	[-39 21 -6]	3.28
Lateral OFC	7	[45 39 -6]	3.10
Dorsolateral PFC	15	[45 36 18]	3.02
Caudate	6	[-9 12 9]	3.01

Supplemental table 4. Regions correlating with the discounted utility (V) of each option in the placebo group alone.

Supplemental Tables 5-7 detail the full results of the L-Dopa-Placebo difference contrasts referred to in the main text and in Figures 3 and 4.

REGION	CLUSTER SIZE	MNI COORDINATES	Z VALUE
Right caudate	114	[18 12 9]	3.88
Left caudate		[-3 -6 6]	3.60
Thalamus		[6 0 9]	3.20
Right putamen / insula	9	[30 -24 6]	3.70
Left putamen / insula	10	[-30 -15 -3]	3.47
Right striatum	5	[24 -9 6]	3.25
Left superior temporal gyrus	12	[-48 9 -9]	3.20
Left insula	6	[-39 -24 12]	3.03
Subgenual cingulate cortex	6	[3 48 -6]	2.97
Inferior frontal gyrus / lateral orbital	7	[-39 21 -15]	2.97

Supplemental Table 5. Discount (D) regions which were more active in L-Dopa than placebo conditions (see Fig 3a).

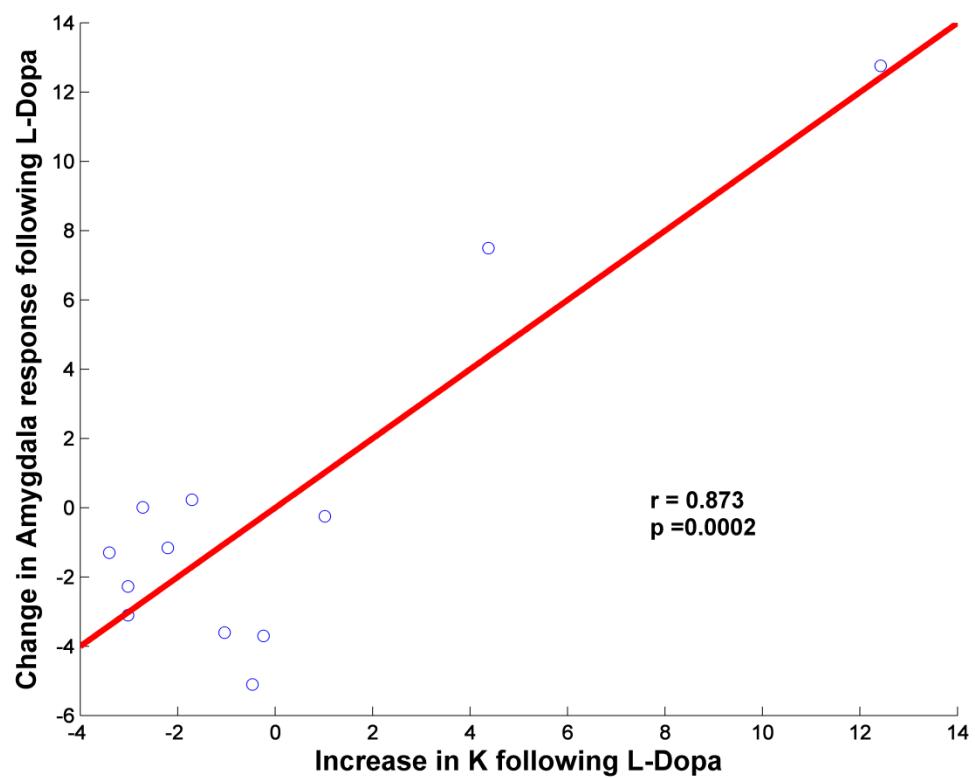
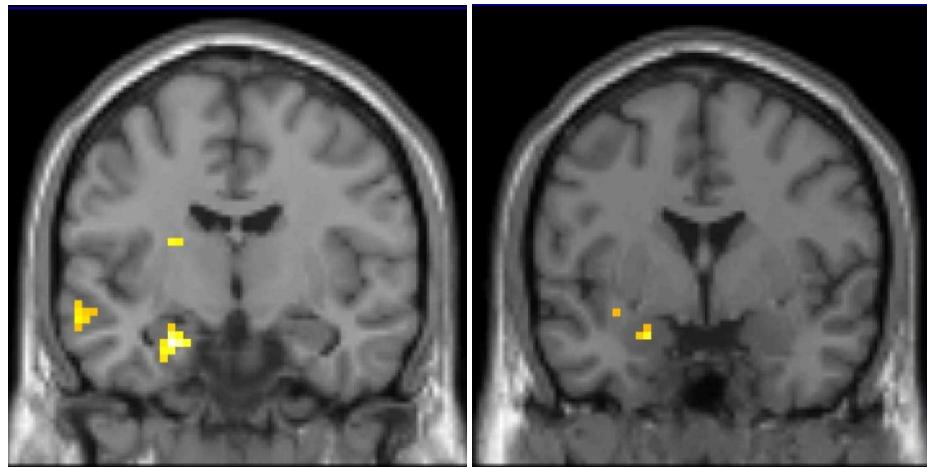
REGION	CLUSTER SIZE	MNI COORDINATES	Z VALUE
Occipital gyrus	28	[-15 -51 9]	4.13
Cingulate gyrus		[-9 -54 3]	3.49
Precuneus / striate cortex	88	[3 -81 21]	4.04
Left insula	28	[-42 -6 0]	4.00
Right parietal operculum	34	[66 -18 15]	4.00
Right caudate	32	[24 7 -3] [15 18 0]	3.50 3.44
Inferior frontal gyrus (lateral)	13	[-60 9 9]	3.38
Occipital gyrus	8	[21 -75 18]	3.37
Medial temporal gyrus	9	[-54 3 -15]	3.35
Occipital gyrus	11	[36 -45 -12]	3.26
Superior temporal gyrus	9	[54 -6 -3]	3.23
Occipital gyrus	18	[12 -57 9]	3.17
Insula	9	[-30 -30 21]	3.14
Putamen	21	[-24 -12 6]	3.13
Putamen/insula		[-33 -18 6]	3.03
Insula	9	[36 -9 -6]	3.04
Superior temporal gyrus	7	[48 3 -12]	3.02
Superior temporal gyrus	7	[-57 -27 6]	3.00
Insula	9	[45 9 -3]	2.95

Supplemental Table 6. Discounted utility (V) regions which were more active in Placebo than L-Dopa conditions (see Fig 3b).

REGION	CLUSTER SIZE	MNI COORDINATES	Z VALUE
Cerebellum	12	[33 -78 -33]	4.09
Cerebellum	39	[9 -66 -30]	3.88
Left amygdala	38	[-24 3 -21] [-15 -3 -21]	3.83 3.80
Right inferior temporal cortex / amygdala	61	[33 -6 -36] [24 -6 -30] [39 -27 -24]	3.78 3.33 3.24
Right inferior temporal gyrus	18	[39 12 -33]	3.60
Brainstem	9	[-6 -24 30]	3.50
Left inferior temporal gyrus	10	[-30 -9 -33]	3.50
Occipital gyrus	13	[-3 -57 6]	3.27
Medial temporal gyrus	12	[-57 -3 -21]	3.20

Supplemental Table 7. Discount (D) regions which covaried with the degree to which choice became more impulsive on a subject-by-subject basis in L-Dopa – placebo conditions (see Fig 4).

Supplemental Figure 2 and Table 8 detail the results of an alternative analysis on individual subject susceptibility to impulsivity under the influence of L-Dopa. In the original analysis (results, Figure 4 and Supplemental Table 7), the change in the number of sooner choices from the placebo to the L-Dopa condition was used as a metric of increased impulsivity across conditions. In this alternate covariate analysis, the change in estimated K value across conditions was used instead (see results). Here, the larger the increase in K , the more impulsive (in terms of temporal discounting) the subject became under L-Dopa.



Supplemental Figure 2. Upper panel Statistical parametric maps showing areas expressing an overall sensitivity to the discount factor (in L-Dopa minus placebo conditions) and which covaried with the degree to which the discount rate increased following L-Dopa, relative to placebo, on a subject-by-subject basis. A significant correlation was observed in the amygdala (see Supplemental Table 8). **Lower panel** Change in BOLD response in the amygdala (in response to reward proximity) in relation to the degree to which each subject became more temporally impulsive under L-Dopa. Values are mean corrected and scaled automatically by SPM.

REGION	CLUSTER SIZE	MNI COORDINATES	Z VALUE
Fusiform gyrus	47	[-30 -3 -30]	3.75
Amygdala (left)		[-24 -9 -24]	3.71
Amygdala (left)		[-21 0 -21]	3.11
Superior/medial frontal gyrus	18	[-12 57 36] [-27 39 36]	3.72 2.85
Internal capsule	10	[-21 -12 18]	3.66
Cerebellum	29	[12 -66 -24] [-6 -69 -33] [3 -72 -30]	3.65 2.99 2.86
Cerebellum	10	[-21 -39 -36]	3.56
Fusiform gyrus	12	[33 -3 -39]	3.54
Inferior temporal gyrus	5	[-42 6 -36]	3.48
Cerebellum	24	[15 -39 -33]	3.45
Superior frontal gyrus	6	[21 45 36]	3.32

Supplemental Table 8. Discount (D) regions which covaried with the degree to which K increased, from placebo to the L-Dopa condition, on a subject-by-subject basis (see Supplemental Figure 2).